

ENGINEERING HERITAGE WESTERN AUSTRALIA

WESTERN AUSTRALIAN ENGINEERING ORAL HISTORY PROGRAM

Transcript of Interview with

Dr JOHN WAGER

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Initial Interview	27 November 2012
Venue	West Perth
Duration	2 hours 25 minutes

NOTES TO THE READER ON INTERPRETATION OF THIS TRANSCRIPT

Readers of this oral history transcript need to be aware that it is a near verbatim transcript of the words as spoken during the interview that was conducted in the form of a natural conversation between the interviewer and the person being interviewed. Some minor changes have been made to facilitate the flow of the document.

Much of what is said in such interviews relies upon the accuracy of the memory of the person being interviewed and readers should bear this in mind and judge for themselves how factually accurate the material is. The interviewer has sought to clarify or verify facts and statements made during the interview where this seemed appropriate.

The views and opinions expressed within the transcript are those of the person expressing them in the interview.

Please refer to the notes on the following page to aid interpretation of the transcript.

Note 1

The recording comprises eight parts in 'wav.' format. It runs for a total of 2 hours and 25 minutes.

Note 2

Where the interviewer has used words such as 'Yes', 'Right' or 'OK' as an encouragement, but not as anything else then these words have not been transcribed unless they are relevant for the context.

Note 3

The interviewer has inserted occasional words (which are not in the original recording) into the transcript in order to clarify the context of what was being said. These words are shown in the form [*they would say*].

Note 4

Where a sentence has a series of dots in the text such as this indicates that the speaker paused, the recording was not clear enough to transcribe accurately what was said or the following speaker interrupted what was being said.

Note 5

Numbered footnotes have been provided in the text in order to assist the reader.

Note 6

The interviewer is referred to as 'Ayre' in the transcript and to the subject speaker is referred to as 'Wager'.

Track Speaker

- 1 Ayre This is an interview with Dr John Wager who is speaking with Doug Ayre who is working as a volunteer in the Engineering Heritage Western Australia Oral History Program. This interview will form part of an oral history archive which will be housed at Engineers Australia in West Perth and Canberra. Copies may be also be lodged at the Battye Library.
- Before we begin I need to make sure you understand your rights in relation to this interview. Do you understand that you will control access to the information given during this interview by filling in the consent form?
- Wager Yes.
- Ayre Do we have your permission to make a transcript of this recording?
- Wager Yes.
- Ayre Thank you. You may terminate this interview at any stage.
- This interview is taking place on Tuesday the 27th of November 2012 at West Perth.
- Dr Wager, may I call you John?
- Wager Certainly.
- Ayre Thank you.
- Well, I don't know where you'd like to start but simply, I think, probably with schooling - primary and secondary schooling.
- Would you like to tell me a little about that please?
- Wager Yes. Primary schooling was at Subiaco State School.
- My family home was in West Subiaco and that was interrupted by Word War II when I was one of the evacuees to my uncle's farm in 1942/43 at Koorda where I attended a one-room school which was a great experience. It gave me a broad grasp of education because you could overhear courses below you and courses above you.
- Then after the war the family had difficulty in resuming possession of the house in Gloster Street, West Subiaco, because it was let during the war. Both my uncle and my father served during the war but the house, being let by regulation, couldn't be resumed without some difficulty. So during that period we were effectively camping in my grandfather's cottage down at South Cottesloe near Fremantle.
- From there I, at Subiaco [school], managed to secure a scholarship to [Perth] Modern School and that background, and also the period of secondary education, just fostered my strong interest, life-long interest, in things mechanical. For the Cottesloe area it was the period when Fremantle Harbour was very active during the war of course. As a youngster I was able to ride my push-bike down there to see the not-publicised activity of the submarine fleets. The American

submarine fleet after Pearl Harbour had migrated down to the Philippines and then with further Japanese incursion came to Fremantle and the British had a submarine fleet there and the Dutch from what was then Batavia, Dutch East Indies. I think all in all there were 160 submarines in Fremantle, not at once but over the period of the war.

Wager There was in February, was it February 1942¹, a very dramatic fire in Fremantle Harbour. None of this reached the press obviously. Fremantle Harbour was also [a repair base] during World War II and ships that had suffered bombardment - many quite close off the West Australian coast - were in for repairs and apparently a welder on one of these ships in, [it] was the *Panamanian*, was welding and a piece of cotton waste ignited and absent-mindedly he threw it over-board. But, of course, it wasn't virgin water into which he threw it. It was oil-soaked water from the shipping and submarine bilges and there was a mighty fire.

The bulk of the port was evacuated but the smoke was clearly visible from [my] residence in South Cottesloe. So I trundled down. It was quite an experience.

Wager On happier occasions after the war to see Fremantle as it was [then] was quite an experience and that evoked a further interest in marine engines. There were ships running on the coast, the Westralia and a whole slew that did the eastern states run. There were the P&O and the [Orient] liners and triple-screw ships. I remember there was one vessel from South Africa and I wondered if the hull was long enough to carry its name. It was *Johan Van Olden Barneveldt* which was interesting. I was increasingly interested in the engines and the means of transmission. It's been a lifelong interest.

Ayre Did you get the opportunity to look at such things as a boy?

Wager Yes. Even although it certainly wouldn't be possible today to hitch a ride as a young man on some of the tugs. Quite interesting and, of course, to wander down in to the engine rooms.

That was a very interesting period. My grandfather's cottage was in what was known in the 1930s as Ocean Street but in 1942 the title was changed to MacArthur Street.

Ayre It was in recognition of General MacArthur, do you think?

Wager Yes indeed but also because of the then heavy traffic that I was able to observe, as military would be coming off ships from all sources, and they were being directed down Ocean Street along the water-front to Swanbourne and the military camp.

Ayre So just coming back to your time at high school, which I think you said was Perth Modern School, tell me a little about your time there.

Wager Well that was very interesting. Modern School was co-educational which was very positive. That period, I mean the education, was

¹ This subsequently advised as having been in January 1945.

interesting. I had a great interest in languages as well as an interest in science and I had to make a choice in the penultimate year whether I'd continue studies in French and German or take further studies in science, Physics [and] Chemistry. I liked the whole range so I ended up doing chemistry separately at Perth Tech. There were some very good teachers but I think it was one's contemporaries in that environment that just encouraged learning.

Wager Also in that high school era I was able to follow interesting aircraft. I used to cycle in the 1940s. [In] 1948, [I would go] up to Perth Airport which was at Maylands in a grass paddock and it housed MacRobertson Miller Airlines, Airlines WA, Jimmy Wood's Fly-to-Rottnest, and also the Royal Aero Club.

Being interesting in aircraft engines I used to, I think 'hang around' was the phrase the Royal Aero Club used. It was interesting. Being post-war there were some returned servicemen who had personal private flying licenses and were flying just to keep their licence [current].

The Tiger Moth has got two seats, two cockpits, and I often found myself in the forward cockpit.

Ayre As the observer?

Wager Well sometimes as a very 'surprised' observer because it was legal then to perform aerobatics over what now is very much a settled area. Over Mount Henry I flew inverted and looped. The pilot in the rear cockpit knew what he was doing but it was my surprise.

Ayre Well hopefully you had a good seat belt then?

Wager Oh yes.

Ayre Because they were open cockpit weren't they?

Wager Also by this time the family had retained possession of the family home in West Subiaco and that bicycle of mine carried me out to the site of the erstwhile West Subiaco airfield.

Ayre Really? I didn't know there was such a thing?

Wager Many folk don't. It was out in what then was bush, at the site of where McGillivray Oval now is of UWA. Latterly I've learnt more about it. I knew then that it had been the site of the WA Gliding Club but also an airfield for light aircraft.

That's when I learnt about a very intrepid German-origin gentleman. Hewart C Ittershagen. He had a factory making wicker-furniture in Shenton Park. It was visible from the railway at Shenton Park station. You [could] see his name on the factory walls. Earlier, before my time, in the 1920s, he had realised the burgeoning activity of farming in Western Australia and he secured the licence [to import] single-cylinder Lanz Bulldog tractors. That was all very interesting. He also had the entrepreneurial perspicacity to also import not one but two German aircraft, single monoplanes [with] two cockpits and he hired a technician and a pilot to service these

farm tractors - the Lanz Bulldogs.

That was interesting. It just furthered my interest in aircraft engines.

Ayre The thought of a single-cylinder tractor conjures up clouds of diesel smoke to me.

Wager Starting it was a traumatic event. Even operating, the thing pulsed.

Ayre Yes, I have a memory of starting up the old single-cylinder generators out in the bush, you know. Yes, they took some starting didn't they?

Wager Mmm.

Ayre Alright. Well that's quite fascinating.

So whilst at Perth Modern, then, you made a decision that you would study the languages, and then chemistry in evening school. What did you, sort of, graduate with from Perth Modern then?

Wager Oh, with a further desire to follow engineering.

Ayre Yes, but subjects that you completed may I ask?

Wager Oh from memory Maths, Physics and then English, French [and] German.

Ayre Yes okay. And that [was] associated with a fervent desire to study engineering?

Wager Mmm.

Ayre It's interesting isn't it where these fervent desires come from?

Wager Also where they lead later in life. You know, folks say 'well what's the use of French and why are you studying German?' Well, later in life I found out.

Ayre Please tell me.

Wager Well, we're leaping ahead many decades.

Ayre That's alright.

Wager In later life I found myself invited to become, and [was] then elected, a member of an international research group which was founded in 1952 in Paris. It was called (unsurprisingly [in] French) CIRP *Committee International pour Research et Production* and papers were accepted in English, French or German. At that time I was a senior lecturer at the University of Western Australia and I was fortunate to be invited to become a member of CIRP. Also being a member, I was encouraged into research and encouraged my graduate students into research that was relevant to their interests i.e. CIRP interests.

Ayre The languages that you'd studied at school obviously facilitated that did they?

Wager Yes.

Ayre Interesting isn't it where it leads?

- Wager And in many other places.
- Ayre Yes okay. Well we might touch on that later. I'll just pause there.
- 2 Ayre So having left Perth Modern School with a grounding in languages and some science studies, Chemistry at evening class, you went on to university, I presume, did you?
- Wager Mmm.
- Ayre Could you tell me a little about your university studies?
- Wager Oh well it was my first year in 1950 and it was a very different Perth in 1950. The Narrows Bridge didn't exist nor did the freeway. Perth Airport as I mentioned was on the grassed suburb in Maylands. There were very few domestic buildings south of the river. Certainly no skyscrapers in the city. Two of the tallest buildings were Royal Perth Hospital and the Gledden Building which was then the home of the Institution of Engineers Australia.
- Basic transport in 1950 was by steam train or by tram although a relatively new electric trolley bus did run from St George's Terrace, along Mounts Bay Road past the then-thriving Crawley Baths, along Stirling Highway to the fire station in Claremont. The tram came from Perth via Rokeby Road, Subiaco, to Nedlands and then along Broadway close to the university, to the river at Nedlands Baths. A four-wheeled tram also tottered over the causeway around Perth Water to South Perth headed for the zoo.
- Ayre What did you call it? A four-wheeled tram?
- Wager Yes.
- Ayre How was that different to an ordinary tram then?
- Wager Ordinary trams usually have bogies, a bogey being a cluster of four wheels, fore and aft, but to negotiate the many curves in that track and also the nature of the track this was simply a two-axled machine.
- Which also had a fascinating thing and it caught my eye as a potential mechanical engineer. It was a device that was on the bulkhead of the tram, so, seated as a passenger, you could see this circular device about the diameter of a large wall clock. The bottom half of the circumference was opaque but the top was clear and showed the then-visible portion of a disc and the disc had advertisements on it. The rocking of the tram because of this circuitous route must have encouraged some brilliant advertising agency to have a small pendulum at the bottom of the disc so while the tram was rocking along there was a tantalising question. I remember one was 'Who is your hatter?' Everybody wore a hat in those days and when it struck a violent curve the thing would roll over and reveal the answer. In this case it was 'John R Saunders in Wellington Street'.
- Ayre That made a profound impression on you didn't it?
- Wager Well it made a profound impression on me regarding the ingenuity of the advertiser to distract the attention of the passengers from the

awkwardness of the ride.

Ayre Yes, that's incredible.

Wager I've never seen one since.

Ayre No.

Wager Well I hope trams and buses have a got a much more leisurely ride.

Ayre Yes indeed. Quite fascinating. I wonder what happened to it? Hopefully it's in a museum somewhere.

Wager Well yes. Maybe out at Whiteman Park.

Ayre Yes, it would be worthwhile looking.

One of the things that always intrigued me about university students of your era is that I suspect that many of your colleagues were returned servicemen weren't they?

Wager Oh yes, very much so.

Ayre Was that beneficial in any way?

Wager Oh in many ways. Like Perth the university was smaller then. South of Winthrop Hall and the administration buildings [and] the science bloc there was nothing but open space, with two large ovals and lines of trees. The Reid Library wasn't yet built and so the engineering school was on the far eastern side of the campus near the edge of the river, well away from Winthrop Hall and buildings. That led to a feeling of solidarity within the engineering school and a feeling of events in the world.

Those returned servicemen you mentioned, some were still there during my course and they certainly enlightened our view of the world and a feeling in me personally to want to see more of the world.

They also livened up the course-work and the presentations. They took no nonsense from the lecturers. They had a good relationship but they wanted, if you like, value for money for a course that meant a lot to them and meant even more because they had a clearer perspective of where they wanted to go.

Ayre Yes, I remember doing my part-time studies at university and the lecturer saying with a little 'tongue in cheek' that she thoroughly enjoyed having 'mature age' students in her course and I suspect what you're saying was true even then. They used to say it the way it was, you know.

Alright, so how long did you spend at UWA doing your first degree then?

Wager At that time the engineering course was of five year duration and it had been planned to [include] a one year work-experience which I also met later in my career, but at that time it was a five year course and I happened to be studying just what was called a transition period. It was still the equivalent of one full-year experience in

industry but it was broken into two parts. For the last half of the second year including the summer vacation one was expected to gain industry experience and then in the following year the second half of the third year including the summer vacation was available.

So this gave me two chances to gain experience and for the first I managed to get a post at [the] Commonwealth Aircraft [Corporation] in Melbourne and that was fascinating. I, being always interested in aircraft engines and mechanical design, was very interested in the work that was going on in maintenance of twin-row radial engines. The tolerancing in any simple engine even a single-cylinder motor cycle has got many combinations of tolerances and clearances to enable it to work for many hours and many miles. But a twin-row radial engine with a double-throw crankshaft, each with seven or nine cylinders, is a magnificent mechanical device.

Also in that relatively brief time I was able to get some experience at jet-engine test beds and that was quite fascinating looking at the design of the devices to measure the thrust of the, then, Rolls Royce Nene engines. They were then being built under licence in Australia and they powered the Vampire, the de Havilland Vampire. The test bed to measure the thrust was a very interesting device but the thrust itself was something. I was interested in the 5,000 lbs of thrust that the Nene generated.

Also during that time at Commonwealth Aircraft I was able to see the installations under way for the Rolls Royce Avon which was [not] a centrifugal compressor. The Avon was an axial flow compressor and it generated the, then, amazing thrust of 10,000 lbs. In latter years, slightly before my retirement, I found myself on a mission in Sri Lanka and I had flown there in a Boeing 777 and [as] they didn't have any covered walkways I had to go down a set of steps which enabled me to look into the gaping mouth of a Rolls Royce 211 with about 64,000 lbs of thrust.

Ayre You could just about walk into them can't you?

Wager Yes. That was amazing. And in the second year I was doubly fortunate because I got a job, not as an engineering student poking round 'looking over Nellie's shoulder', but as a machine-shop inspector in the gear-cutting department.

I was very fortunate that my guide and mentor there was one of a small number of folk who've made a real influence on my life. His name was Bert Webster. He was the local Superintendent and he said to me very early in the piece. 'John' he said 'one thing you've got to remember, in this department we don't cut gears, we just cut carefully the spaces between them.'

What I learnt there as well as being able to inspect was the result of machines generating involute curves. It's a fascinating experience, a fascinating project, how to design a gear, how to make a gear and the process of rough-cutting, finish-cutting, finish-grinding.

Ayre From what I remember of my time gears are really an elegant piece of mathematics aren't they?

Wager Mmm, they are.

Ayre So you would have been familiar and trained in the machining technology of the day?

Wager Oh yes.

Ayre Okay. What sort of machining did they use?

Wager Well gear-generating cutters. It's based on the mathematical curve, the involute, which can be imagined as unrolling a piece of cord from the circumference, the periphery of a cylinder. As that cord, which is fastened to the cylinder, is unwound from its surface any one point on the surface of the cord generates, in space, an involute curve and so the nature of the involute curve is a function of the diameter of that hypothetical cylinder. That means mathematically for an infinite cylinder the curve becomes a straight line and that means that by creating a straight line cutter, but rolling that, or rolling around the work material while that cutter is oscillating, you actually create an involute in the blank material. So there were machines of that type.

Ayre So the mathematics was not only in the design of the gear facings but also the actual machining that did the reproduction of it?

Wager Oh very much so.

Ayre Alright. I'd just like to revisit something. You commented on radial engines earlier? And you said seven or nine cylinders? I've often wondered why, it's always seemed to me fairly common, that radial engines had an uneven number of cylinders. Why was that?

Wager Largely for vibration.

Ayre So how did that help then?

Wager Well, when you look at the firing sequence, instead of them going round [sequentially] which would generate a torque disturbance it became progressively circular.

Ayre Yes, I often wondered about that.

Wager A vibration problem. In the history of radial engines there were even endeavours to create four banks of radials which would be a frightening assembly [not only] from a geometric design point of view but also [from a] mechanical engineering manufacturing point of view.

Ayre So you had some practical exposure during your first degree?

Wager Oh yes, and that time at Chamberlains really generated my honours degree thesis. The thesis was on the stresses induced in gear teeth using photoelasticity. You understand photoelasticity is a means then widely known? I didn't create it but I used it. Photoelasticity uses photo-elastic responsive material. They're clear transparent materials but when subject to stress they cause a single frequency monochromatic light to deflect in a certain way that leaves alternating

light and dark areas denoting the amount of stress and that gives a two-dimensional stress pattern of the contact of gear teeth.

Ayre I think I saw that similar effect used with polarised light.

So that gave you a visual image of what was actually happening in practice did it?

Wager Mmm. That was also quite interesting too because the photographs, the records that they obtained, showed that the peak shear stress obviously occurred near the point of contact because it is effectively geometrically a single point. Well it's a line of contact in the actual gear, but a point in two dimensions. The [maximum shear stress] between the gears [was just] below the surface and that related back to observations I'd made at Chamberlains that sometimes worn gears had shown an exfoliation. That is the surface had come away because of higher stress slightly below the surface.

Ayre So that caused the surface to actually detach?

Wager Exfoliate.

Ayre And if that continued then did that mean that the gear tooth eventually broke away completely?

Wager Oh yes. Wore away.

Ayre It's interesting that all is not obvious is it?

Wager I've been learning fascinating things all my life.

Ayre So you did your honours first class honours mechanical?

Wager Mmm.

Ayre And I think that would have been, what, 1954?

Wager Fifty four, yes.

Ayre What did you go on to do after that?

Wager Ah well, because of the earlier interest that had been evoked in [the wider world] I applied for a graduate apprenticeship in England with English Electric and to my pleasant surprise that was granted. So I spent two years in Preston, Lancashire

Ayre Ah, bah gum lad.

Wager *Laughter*

Yes, we had to learn a different language. But they were lovely folk.

Ayre Not a language you learned at school obviously?

Wager No. But they had some lovely idiom as well that we learned to understand and to master.

That was fascinating because then English Electric was virtually in its heyday, because not very long afterwards English Electric became subsumed, it was taken over. Up to that time it had been really an engineers' company run by engineers.

During World War II English Electric had taken over Napier Aircraft

Engines so there was another link with aircraft engines.

My time at Preston was working on much heavier diesel engines for locomotives. This was at the time when British Rail, immediate post-war, was working assiduously to develop electric traction. But it needed something for an immediate post-war interim and [so] they turned to the Napier Deltic which had been developed by Napier as a high speed motor torpedo boat engine. But English Electric, with Napier's obvious involvement, used not one but two Deltics in a very high-powered Deltic diesel-electric locomotive.

Ayre The Deltic was an internal combustion diesel was it?

Wager Yes, it was two-stroke diesel but in a fascinating configuration. I think folk are aware of an opposed-piston engine which is effectively a two-stroke diesel and has no cylinder head. It's got [one] cylinder, two pistons, two connecting rods and two crankshafts. With the gears coupling. But the Deltic has got three of these arrangements in a D or Deltic [triangle] arrangement. Therefore three crankshafts, six pistons and a lot of horsepower coming out, and coming out in a fascinating gearing arrangement at the forward end because those three crankshafts have to transmit their output torque to a gear cluster finishing in a central output shaft to, in this case, in the diesel locomotive, to the generator.

Ayre Why did they have a diesel electric combination for a power unit?

Wager Oh well, the long-term aim was straight electric, but the situation of the track and the permanent structure had suffered so much during the war that although they were working on that, the diesel electric was the interim answer.

Ayre Alright. So you spent two years, did you say, in Preston?

Wager Two years.

Ayre On the subject of English Electric didn't they produce the Canberra bomber?

Wager Yes they did. Yes, and I found that fascinating. It really was an engineers' company run by engineers.

My work was in the West Works down towards the port across a cobbled street. And in the West Works they were producing diesel electric locomotives for Australia, what was then Malaya, South Africa, New Zealand and also British Rail with the Deltics. But cross that cobbled street and you were in the aircraft factory which during World War II, since 1935, had been converted to make four-engined aircraft not Lancasters but ...

Ayre Well perhaps I can throw some names out? Manchesters?

Wager Yes Manchesters.²

Ayre Yes, because they had a Stirling as well didn't they, but I'm not sure

² Subsequently corrected to refer to the Halifax.

who made that. Manchester bomber.

Wager But you're quite right, while I was there, yes [the] English Electric Canberra which served very effectively for decades.

Ayre Decades didn't it?

Wager And also what was called the Lightning.

Ayre The P1. Yes I remember that well as a boy. It used to astound me.

Wager So in my lunch breaks, although it was slightly illegal, I didn't have an appropriate pass [so] I used my dusty overalls to gain admittance, just to see the assembly works.

Ayre Fascinating. I can imagine.

So you didn't at that time develop in to an aircraft engineer then did you?

Wager No.

Ayre Still stayed with engines did you?

Wager Mmm.

No, my forward thinking was to stay in diesel-electric possibly in Australia.

3 Ayre So what happened next after your spell in Preston?

Wager Ah well, towards the end of my time with English Electric I was casting around for future positions and I learnt of a position for a lecturer in mechanical engineering at the University of Western Australia, and I applied, and to my pleasant surprise it was awarded [to me] and that started quite a different thread for me.

I found academic life extremely interesting because, as I think I've indicated, I've got a, sort of, wide interest in things mechanical and I think a man much wiser than I said 'he who will teach must learn' and I started learning. I learnt a lot from my early students too. Many of them didn't realise I was only a couple of years ahead of them.

The more I got involved with academia the more I found quite a freedom. From a research point of view there was a lot of freedom [with] what you chose to study. From a teaching point of view there was a freedom in the sense that when I wanted to take a small group of students to visit a particular plant, or a company, under the university banner you got an easy access. If I was an engineer for the Henry Ford Company or General Motors, you know, there'd be some measure of constraints. I found that earlier freedom I mentioned of choosing research such that I could continue my interest in precision machining or, more relevantly, how to measure it.

There are three significant phases that I found myself responsible for teaching. That is the design of components or assemblies, the machining - how to actually create them - but having created them, how to measure them so that you know what you've got. That measuring [of] them, the study of metrology, was one of my teaching

roles and that led to my Masters thesis. I was interested in, what was then rather widely used, pneumatic gauging.

Pneumatic gauging consists of a small, precise, orifice through which air at a known pressure is passed and as that orifice is presented to a surface, [and] the nearer it gets to the surface, the flow varies because of the escape around the periphery of the orifice presented by the surface. So that was well known and well practiced but the question in my mind was, because I had become interested in precision grinding like the grinding of gears where the dimensions become relevant, what would happen if the surface was not flat but curved? And again, what would happen if the surface was flat but not smooth?

So I ran sequences of experiments of smooth surfaces becoming rough, getting a relationship between the measurement indicated by the pressure variation, and therefore the dimension compared to surface roughness. Also with gears if you want to measure the roughness of a gear, which is a curved surface, to what extent does that curvature govern the result you might get using pneumatic gauging?

Ayre Yes. Forgive me, I'm an electrical engineer as you know, so I'll excuse my ignorance that way, but what technology would you use to get the most precise finish on a piece of metal?

Wager Oh, well, fine grinding. I've already mentioned CIRP; a lot of my research students were working on that, very fine grinding and the influence of a grinding wheel - the grinding surface - and the resulting work profile. But, with fine grinding and then, once that's achieved, lapping and then honing.

Ayre What is lapping?

Wager Lapping is using a pad [with a fine] grinding surface like powder which is an abrasive but gradually reducing the high peaks. The word high and peak becomes increasingly relative when you get down to micrometres. What's high and what's a peak.

Ayre Can you get something perfectly flat?

Wager Oh yes optically. Well even an optical flat has got its [small variations]. But, of course, that process is very well known and well practiced.

Ayre Yes of course. I suppose in the end you end up coming down to the molecular level don't you?

Wager Yes, oh yes, and, of course, when one does that you can actually remove molecules.

Ayre Yes indeed.

Wager That's not mechanical engineering.

Ayre No. Fascinating though isn't it?

Alright, so you completed your Masters and what happened after that from an academic point of view?

- Wager Well I found that academic life and I were reasonably well suited and I was quite happy in the role but it also became obvious to me that to proceed any further in academia I needed a PhD and so I looked around me. I found some of my contemporaries had been attempting a part-time PhD and they were having all sorts of difficulties because they had to cope with family, and mortgages, and lawn mowers, and overdrafts, and teaching. So I said to my lovely wife ‘why don’t you and I and our three very young children pack up, rent our home [out] and take a deep breath and tackle a three-year PhD overseas?’
- She readily agreed and I owe her a lot for that decision and also for creating not a house, which was in married student quarters in Indiana USA, but also a home.
- I chose Purdue University in Indiana because of its industrial engineering degree and I chose a particular major professor [not only] because of his combination of knowledge of industrial engineering and organising for manufacture but also understanding of the methods of manufacture, machining, cutting, grinding and so on.
- I managed to complete it a little bit over the three years. Three years and three months. But it was quite a demanding exercise. My lovely wife - and my youngsters were in primary school - I’ve often asked my youngsters, who now have careers and family of their own, whether those three years were a constraint, a limitation, and they said ‘oh no [it was] a wonderful experience.’ I’m sure they learnt geography simply by being there and they learnt sociology by just living there. It’s quite an education to spend three years in a country other than Australia.
- Ayre Indeed, I can believe that.
- Wager Well, I had an apprenticeship in Lancashire.
- Ayre Well that’s a different world.
- Yes, but you’re right. I mean social skills come from practicing them don’t they?
- Wager Mmm. I found one or two of my academic fellows had families who didn’t adjust. Their children somehow had difficulty coping but, no, my youngsters made friends readily. They had some problems but being three of them collectively they overcame much.
- Ayre Good. So you went to Purdue University. Did you go on a scholarship or something like that?
- Wager Oh yes. Well I readily give thanks to the university³ for giving me a leave for those three years but also I thank the Fulbright Foundation for a travel grant. Without those two [grants] it would have been very difficult.
- Ayre They’re significant investments in you as a person aren’t they?
- Wager Yes, which I appreciated.

³ The University of Western Australia

Ayre I'm sure that's been returned in kind many times but it takes the existence of arrangements, and organisations, doesn't it to make that happen?

Wager Yes, and learning what's available too.

Ayre Did you have any exposure to manufacturing industry in the United States?

Wager Oh yes, very much.

Ayre Tell me a little about that.

Wager Well it was really manufacturing of components. For example, there was a company in the north-east of Indiana that specialised in making General Motors head-lamps, tail-lamps, turn-lamps, indicator-lamps, any sort of lamp. They were all plastic, of course, but the engineering of this required the making of moulds. Metal moulds into which the plastic is forcibly extruded or intruded.

I found that fascinating, you know, the extent to which industry was wide-spread and beyond their home base of Detroit.

Ayre Well it fascinates me certainly because we take it so much for granted that a large number of component manufacturers produce items that come together on a production line and all fit.

Wager Yes. There's a thing behind that that's called metrology.

Ayre Yes I understand and I'm sure that fascinated you in its time did it?

Wager It also caused problems, of course, during World War II. There had to be an international conference, the ABC Conference, *the American-British-Canadian Conference*, to clear up the differences in tolerances in items made in Britain and shipped to America, nominally to do the same thing. The American dimensions and tolerances were just that little bit different and sometimes they didn't fit. The classic ones, the obvious ones, were the threads. British standard thread, and BSF, and so on, but also in dimension tolerancing it has to be international.

Ayre Yes. That just diverts me a little into the subject of standards because it really means that national standards are one thing but international standards are another doesn't it?

Wager Mmm.

Ayre Have you been involved in the development of international standards?

Wager No, not directly. Very much aware of them in teaching. But no, not directly.

That business of producing headlamps and having to machine a quite smooth surface in a metal mould into which the plastic is injected is totally done by EDM, electric discharge machining. I mean we're all familiar with a lathe, and a grinder, and the like but EDM uses a work piece, an electrode, which has the appropriate surface. The electrode doesn't have to be steel, or metal, or hard. It can be quite soft like a

block of carbon but, being soft and smooth, one can generate a profile that's soft and smooth. This assembly is immersed in the dielectric fluid and a pulsating electrical current is passed causing electrons to be ejected, virtually blasted out of the metal surface, and by controlling the rate, [via] the frequency of the voltage, one can get a finished shape. Obviously the finished shape of the injection of the plastic has to be show-room smooth in geometry and finish and so does the metal mould.

Ayre So that's a form of erosion then?

Wager Yes.

Ayre Hopefully very precisely controlled?

Wager Very precisely controlled.

Ayre Yes.

Wager A number of my graduate students did some work, largely for their education, but they built demonstration EDM machines.

4 Ayre John we've talked about Metrology, and we've talked about machining, and we touched on mass-production and components fitting together, [but] to me, hidden behind that would be a study of statistical analysis, probability of failure, or mismatch, or whatever. Would you comment on that?

When I say 'failure' that's not quite the right term. I'm thinking about 'inaccuracies' really.

Wager Oh yes. Statistics are very important because when you get down to finer and finer tolerances, if you have to create something to a certain length, the result can never be absolutely perfect. It can be just a little bit bigger or a little bit smaller and that range of output if you're producing in quantity production, tens of thousands of them, that length would have a variation that can be plotted. And typically, not necessarily always, but typically it's a Gaussian curve. You know it?

Ayre Yes.

Wager [With] the majority of [the sample being] within so many Standard Deviations [of the mean] and so, for quality control there's the need to define where those limits would be. How small is just still acceptable and how large is just still acceptable. This has been for many decades quite a science in itself.

Ayre Yes. I suppose one of the key issues there is that you're using machinery to do the machining?

Wager Mmmm.

Ayre That machinery, in itself, is being machined and it's 'in the process' [itself] isn't it?

Wager Mmmm.

Ayre So I presume it wears and you're monitoring that as well aren't you?

Yes? You have a smile on your face?

Wager Well I was thinking that my interest in metrology was the reason why, in [1977], I was invited during a university vacation to work in South Korea. They were wanting some lectures on Metrology and setting up a system for measuring the output. This was at the very early stage in South Korea's industrialisation and the lectures that I was to give were essentially in the apprentices' school. It was under an International Monetary Fund mission with United Nations support and I found that fascinating. Very fascinating because the companies from which the apprentices came were the companies making, or starting to make, motor cars.

The motor cars needed injection moulded parts. They were using EDM to generate the components and they readily understood what I was speaking about in terms of tolerancing. Smooth surface finish.

Ayre How long were you there?

Wager Oh, only a month. But it was a very interesting month.

Ayre I can imagine it would be.

Well, you have obviously been involved in a wide range of issues relating to mechanical engineering and production.

I sense a little dilemma there for you in that I wonder whether you were pulled between the academia of mechanical engineering and the production side of things out in the world. Is that fair comment?

Wager Well it wasn't really a dilemma because I found by continuing in my roles, [because] by that time I was an Associate Professor in Mechanical Engineering, I was able [to do this].

I found on my return to Australia, after the PhD, that the subject of my PhD which was the spectrum, the distribution of the life of machine tools, not just in sizes of finished [product] but how long a tool would last if you had an automatic machine. That becomes very crucial to know when you have an automatic [production] line without supervision.

That type of research was of interest to this international group CIRP and I suspect that was one of the reasons I was invited to become one of few Australian members of CIRP.

I found as a member of CIRP that you could only remain an active member if you remained 'active'. That is if you had, or your students had, a paper on a subject of research that was relevant to CIRP every two or three years. Well we managed to do this on a limited financial budget. My research was not extensive. I didn't have many students, certainly not compared with other international members of CIRP. I was quite flattered and most amazed to be treated as a Fellow by folk who were publishers of books that I was recommending to my graduate students.

But through that contact I learnt what the CIRP body was focussing on for research in the coming two or three years so I was able to

direct my students to topics and subjects, that were quite minor in their own right, but became useful or regarded as useful by CIRP in the broader picture.

Ayre You mentioned the wear and tear or breakdown life-expectancy of machines and machine-tools on a production line. I presume the objective is to make sure that a particular item does not break down and disrupt the production line?

Wager Mmm.

Ayre So the philosophy is what? To optimise everything?

Wager Yes, and in optimising you have to look at the statistical distribution of output and decide on factors of safety and risk assessment.

Ayre Alright. Well perhaps we can touch on factors of safety and risk assessment?

I think you developed - evolved may be a better word - a significant interest in Occupational Health and Safety did you not?

Wager Mmmm.

Ayre How did that come about?

Wager It came about in a rather interesting way. I finished my first degree effectively at the tail-end of 1954 but when I was granted the graduate apprenticeship in England that was not tenable until June of 1955. So being slightly impecunious, which means 'broke', I found myself a job for the Ford Company, down in North Fremantle, in the building that's now a brewery. At that time the Ford Company was importing in to WA V8 engines produced in Geelong and custom-line bodies from Broadmeadows and putting them together.

While doing this, and remembering this was an era when [steel-capped] safety boots were not widely known and used, and certainly complaining to, or suing, an employer was unthinkable, I was working one day when a V8 engine rolled on to my right foot and it crushed my big toe. I thought no more about it. For a week it was painful but by the time I eventually got to England my right big toe-nail found itself in three parts. One part was growing normally and the other two were in-growing fiercely. As a result the surgeon at the Preston Royal Infirmary removed the nail and the nail bed and wrapped up [what was left of] the toe.

That started me thinking, so that when I resumed teaching at UWA I included Industrial Safety as a key. It was an interesting unit that I was invited to teach; 'Humans in Industry' with a key focus on Occupational Health and Safety.

Ayre Where did that take you then?

Wager Well, in one way it was relevant to my time in South Korea but essentially it filled what I saw as a need for undergraduates to be aware of the environment that they were to go into. And that was very relevant to a secondary [factor].

You asked me earlier about a dilemma between, if you like, the academic side which I had through CIRP, the research group, and quite another group operating from Cambridge University. Normally when one says 'Cambridge University' you think about long-haired Dons on bicycles riding around Cambridge. But since quite early in the piece [I was thinking about safety in manufacturing]. I think it was about, let me see, 1965 it started.

A lot of these things are started by one man who's got a vision and this gentleman, of whom I'm speaking, was Mike Sharman from Cambridge. He had developed a concept of a one year MBA in industry. I could speak at length about this but it was a fascinating compress of one year - 52 weeks, of awareness. It now goes by the title of ACDMM. The '*Advanced Course in Design, Manufacture and Management*' and it was coalescing most of the topics we've been talking about for folk who have a first degree but who have also convinced a rather hard-headed jury that they, the students, are determined for a career in manufacturing industry.

On two occasions when study leave was falling due [and] it was possible for me to apply, the University of WA granted me leave to become one of the presenters at ACDMM. This was a classic case of 'he would teach will learn' because, yes, I was teaching, but yes, I was learning. ACDMM - oh I could describe it in length but briefly - it's a one-year post-graduate course. By the time I was involved with it the course didn't need to advertise; by word-of-mouth it was popular. In fact what the course [also] did was publish the pathways of its graduates after the ACDMM; where they went, [to] what level - not in any particular company- but what level in a company, and that graph [was] interestingly increasing. The graduates were finding positions [into which] they were readily accepted.

There were a number of things. The course structure had taught-modules but a minimum of those. [There were] visits to companies; each graduate would visit nearly 100 companies over that year. But most relevant were the nine industrial projects with quite specific companies. It was arranged that the graduates, and there were 30 of an intake, the graduates would be working in pairs [but] never the same person in the pair so they learnt to evolve teamwork. The companies had previously been advised of the objective and the nature of the projects. It didn't have to be highly technical machining necessarily. It could be simply organising a marshall yard, or storehouse, or whatever. But the graduates had access to company information.

They had support from base-camp in Cambridge and they had a measure of independence. ACDMM had 10 mini-buses and they had organised these industrial projects in geographic areas of the United Kingdom. Cambridge, from their vast experience of contacts, was able to identify billets, temporary residences, for the graduates.

One criterion for admission into the course was a clean driver's license and the group in a certain area, there might be 10 to 16 of

them in a geographic area, they had to organise themselves into a bus, a driver, and a location. So it was a mixture of do-it-yourself for course presenting.

That was quite educative, quite educative, because at the end of the fortnight - each project ran for two weeks - at the end of the fortnight the team had to present [the outcome] to the company, in the presence of the company and in the presence of ourselves, the administrators and coordinators from Cambridge. It was a three-way assessment.

Obviously the students were being assessed; how did they work as a team, how did they perform, how did they report, with what sort of confidence did they report? The students were [also] invited to report on the company; how well did the company realise what ACDMM was intending to do? We were assessed by the company; how clearly did we explain the need for a project and the nature of the project? And the students; how well did we support them?

You know, we were to visit them a least once during the two weeks, usually twice, to see how they were faring. It was quite an education. It was a very intense 12 months.

Ayre I can imagine.

Wager There was nothing of this [typical] United Kingdom academia - going up to college and going down to college and having a Whitsunday holiday. No, it was go, go, go, and it was very much team building.

Ayre Well the MBA of course took off didn't it?

Wager Mmm.

Ayre Incredible.

Wager Some folk might have raised an eyebrow about attempting an MBA in one year but this was such a coordinated, compressed, and yet effective program.

You mentioned possibly repaying the university. Well, I was very conscious of this. On my return I was able to incorporate aspects of this. Sadly, although I thought about it many times, I was never able to recreate something like ACDMM in Western Australia because, sadly, in Western Australia the manufacturing [industry] that had the [potential interest] - Midland Junction Railway Workshops [had been] producing steam engines for war-time naval work [and] the State Implement Works [with] apprentices in that area, all that has gone. Chamberlain Tractors [had also] gone. The skills of cutting the spaces between the gears had gone.

So I couldn't do that but a lot of the philosophy and the background, particularly the humans in industry aspect I believe, I hope, I was able to convey to my final year students.

Ayre Yes. Dare I say it; you would have found yourself, with the loss of manufacturing industry in Perth, somewhat out on a limb wouldn't you?

- Wager No. Because every year CIRP had a conference. Obviously I was not able to have a paper accepted for every [one] so I wouldn't want to go to [every] conference but I went, over my time at UWA, I went to 2, 4, 6, 8, 10, 12, 14, CIRP conferences.
- So that gave me the academic interest but even that academic approach of CIRP was very much industry oriented. There are industry members of CIRP so I lived vicariously. I didn't feel isolated. I was looking at the world.
- Ayre In fact probably your 'isolation', dare I use the word, drove you to that international approach didn't it?
- Wager Mmm. And I enjoyed it. Personally I revelled in it and I say again I was grateful to UWA for allowing me, encouraging me, for those study leaves.
- Ayre Yes. Alright. So you had a long term membership of CIRP? I think you are an Emeritus Member at the moment aren't you?
- Wager Mmmm.
- Ayre Just looking back at your sabbatical leaves that you had with UWA can you tell me a little bit more about those?
- Wager Yes. CIRP was, sort of, intense conference-specific so that if I could get leave for a week or 10 days I could get lots of information from CIRP. The key information that I was able to get was what the researchers in CIRP were wanting to do for the following year. So I could take that knowledge back home to UWA.
- But [with] the study leave - which was quite generous and certainly much appreciated - I focussed on the Cambridge ACDMM because that enabled me and my wife to be away for a full year working in this compressed MBA in manufacturing. So I learnt a lot about that and I believe I was able to bring that information and motivation back.
- Ayre Yes. I'm sure.
- Wager So no, I didn't feel isolated.
- 5 Ayre Alright, so you had periods of up to one year as a visiting academic or professor. I understand you went to Cranfield Institute of Technology in UK for a while?
- Wager Yes that was a period of six months teaching, effectively, the manufacturing units I'd been teaching at UWA. And that was quite interesting because Cranfield was built on a World War II airfield and so it had an aircraft aspect to it. So I learnt as well as taught there.
- Ayre Oh really, I didn't know that.
- Wager [At the] tail end of the same year '73/'74 - that's the northern academic year - I presented, for a term, lectures in South Africa at Witwatersrand and that was fascinating. It was fascinating to see apartheid in full swing.

Ayre That was in 1974?

Wager Seventy four.

Ayre Really. And what was your reaction to that?

Wager Oh you can understand. Yes, yes, 'you can't sit on that chair that's black.' It looked all white to me.

Ayre Yes.

Wager Yes. An interesting thing occurred there because a very wise Afrikaans member of staff said to me 'John, look, you're obviously interested in manufacturing. What we have been doing to assist Mozambique' - there was a university in Mozambique - 'is to give a one-week course for graduates, graduate mechanical engineers, in industry. We've been doing this for two years [and] it's time to do it again [using you]. Not because we're tired of doing it but because it would be a great experience for you.'

I leapt at the chance because Mozambique had been a Portuguese colony since its creation. The capital city was then known as Lourenco Marques, and there was a University of Lourenco Marques, and I would be otherwise very interested in meeting and learning from the graduate engineers then in industry.

Well, in that week it became doubly interesting because, in addition to meeting with these folk - and these were evening lectures - I interrupt myself there by saying that it was only in the evening - so during the day I had the use of a car and a driver to go exploring so I explored up to the base of the great Limpopo river.

But more relevantly the graduate engineers were interesting. They were very concerned of the fact that the communist rebels, the Frelimo, were approaching from the north and marching south steadily. In fact one graduate engineer was designing for his company an appropriately-weighted two-axle device to be pushed in front of a locomotive on the Mozambique railways such that that device would cause the explosion that might occur if the communists had put explosives in the track. That's the sort of application of mechanical engineering I hadn't quite envisaged.

But it was quite an experience because when I left, after I left, the Frelimo had taken over. What was known as Lourenco Marques has now become Maputo and I had that one week chance for an experience.

That occurred in many facets too because in Johannesburg everything - oh I'm tempted to say was black and white - was defined but in Lourenco Marques it was Portuguese and very European. I mean, these graduate mechanical engineers came to me about half past five and we talked until about ten o'clock, nine thirty [or] ten o'clock, and then they had dinner. At dinner you'd find [that people] ranging from a senior professor to a cleaner might have been around the table. It was refreshingly different.

- Ayre Certainly an enriching experience I suspect.
- Wager Yes. Again I thank the University of WA for the study leave.
- Ayre I think you went on from that to Waterloo University in Canada did you not?
- Wager Yes. That was a little later, Waterloo University. I only taught there for one semester. That was a short study leave I was fortunate to have.
- Waterloo was a very highly organised five-year program. I mentioned earlier in this recording that my undergraduate program was five years. But that was essentially a do-it-yourself year out in industry. We had to arrange our own 'what do-you-do in industry'. Whereas at Waterloo it was very much a program. I think it was several million dollars they had invested into companies who would formally undertake to have undergraduates in their fourth year and because of the relative compactness of manufacturing industry in that part of Canada there was no difficulty although some went across to Vancouver. But it was highly organised.
- That was interesting because I was presenting two units in my teaching. One was a third-year unit. They were good students - good youngsters - not all - [but] very interesting. Then I had one unit to teach in the final year and the difference that one year made - I mean, yes, they were one year older - but in terms of their world focus, their objective [was better defined].
- It reminded me of the question you made earlier about my own experience in my own undergraduate course of having returned servicemen with a clear view of what they wanted and the experience to be able to discuss with staff, if not argue with staff, on certain matters. That was a great education.
- Ayre I think, just going on, you spent some time at the University of Lancaster in the UK?
- Wager Yes, that was 1985/1986 and that's when I really got to know by being involved with this ACDMM man from Cambridge and that was interesting. [While] I was down at Cambridge I became a short-term Fellow of a college in Cambridge, Wolfson College, but that's all I saw of college life. Sort of a one-day visit because I was [somewhat remote] up in Lancashire.
- I think I mentioned briefly the ACDMM would try to gather nine projects in a geographic area largely from the logistic convenience of giving the graduates a number of mini-buses and [a] number of accommodations so that they could organise themselves geographically without too much fuss. Usually on a topic, steel industry for example, or ship building, [now] disappeared but all [industry of] that ilk.
- So the bulk of my time at Lancaster University was spent in industry but in Lancashire and that was fascinating. That's when I really learnt

- the fullness of the ACDMM project.
- Ayre I have to say that, being an Englishman of north country origin, being in Lancashire would have put you right in to the heart of the industrial revolution wouldn't it?
- Wager Mmm.
- Ayre You know, I can really relate to that.
- Wager Well, I had already had my 'literal' apprenticeship with English Electric so I learnt the language and the idiom.
- Ayre Yes. Alright.
- So you went on later to have a spell at Cambridge University?
- Wager Well yes. I mentioned [that it was in] '92/93. This was also in Lancashire, but it was slightly different, although I was in contact with Lancaster University my role in '92/93 was slightly different. In '85/86 I was administering, working on, teaching, existing course structure.
- The way in which the projects were organised by ACDMM were [that] once ACDMM had [the] companies' understanding what the objectives of the projects would be they would go back to those companies for a second year. Their principle was they would never go back for a third year; they just wouldn't approach the companies [again] and when the companies approached them and said 'hey, where are you?' then they knew the companies understood the value to the company of the project. It wasn't a 'Will you help the university by looking after [our people]?' it was 'How can these people help you?'
- Ayre It's a subtle piece of reverse psychology isn't it?
- Wager It was. It was fascinating. I expressed my fascination and they said 'Well, John, we could as before give you six projects to administer but they would be new to you so here's a challenge' they said. 'What we want you to do is to go up to the Darvel Valley in Scotland and find six companies who would agree to undertake a project each.' 'Ooh', I said, 'there's a challenge'.
- Ayre That would have been a challenge.
- Wager Yes. [I asked myself] where's Darvel Valley? So I looked up the atlas and I saw the Darvel Valley included Kilmarnock.⁴
- [I asked myself]; 'who do I know in Kilmarnock? Johnny Walker. Johnny Walker whiskey.' So I phoned Johnny Walker Whiskey and explained [about] Cambridge; I explained ACDMM; I explained student projects. The very patient Occupational Health and Safety man said 'look John we'd love to be involved but right now is not the time because, unfortunately, we've just had to let go some key people and it wouldn't be understood. I now understand the approach of

⁴ Darvel is in Scotland and is the most easterly of the 'valley towns'. It is located between Irvine and Edinburgh about nine miles east of Kilmarnock

ACDMM but no, now's not the time.'

So I thought 'oh, what to do?' So I drove up along the Darvel Valley and I could see that there were lace-making [companies]. Yes, the Scottish folk turned to lace making [and] I could see there might be a possible use of computers for computer-designed making of lace possibly, maybe.

Then when driving through one other little village down towards Kilmarnock I saw a sign, almost a hand-painted sign, that said 'Vesuvius' and I thought 'that's strange. I didn't know there were any volcanos in Scotland'. So I drove back [and] went down this little side street and found this plant and it had the name 'Vesuvius'. So, [as] I didn't want to do a cold entry on them I went back and did some research on this company 'Vesuvius' and what I discovered I found fascinating. It all related to continuous-casting of steel.

Are you familiar with continuous-casting of [metal] on a [production line]?

Ayre No, I'm not.

Wager Normally the historical making of steel is to reduce iron ore in a blast furnace into pig-iron. Then usually the pig-iron is put in to ingots. They get cold and then they're reheated and then they're in a furnace - a Bessemer furnace or whatever - which more finely controls the level of carbon [in order] to produce steel. Then sometimes those red hot ingots are taken, while red hot, and manipulated in-between rollers and they turn into [lengths]. Continuous casting is to take the output from a steel furnace and take it down in to a receptacle which is lined with a heat resistant ceramic.

Ayre So this is molten metal?

Wager Molten metal is poured into this ceramic [receptacle]. It's got four sides and a bottom, and by careful calculation, and thermodynamics, and rate of cooling it becomes known when the molten metal is solidified around the periphery and, of course, around the bottom [and] then up the sides. At an appropriate time the bottom is removed leaving four sides gripping this cup, if you like, of steel. The periphery of the cup of steel is itself solidified [and] the rest is slowly solidifying.

Now by balancing the rate of solidification of the steel those four sides of the mould are slowly being moved down. So as the molten metal is poured in it is solidifying [but] still red hot or white hot.

And then at a certain stage the four sides are quite rapidly moved upwards, and then slowly down, and then upwards. So as a result there's a vertical descending of largely solidified [mass]. Only a small amount of the core might still be liquid but essentially when it reaches a certain level it is red hot, white hot, steel and therefore it is readily rotated [through] 90 degrees by a set of rolls and then while still hot is taken through in segments to become plate, or sheet, or into railway [line], or whatever.

Now the key the key to this is not only the understanding of thermodynamics or the appropriate rate of cooling so [that] you don't have liquid metal all over the place and you do have a solid steel [mass] on which to work.

The key is that one word I mentioned - 'ceramic' - temperature resistant ceramic, and this company, Vesuvius up there in Scotland, was acquiring the chemical ingredients to make these ceramic moulds. It was quite a steady business because although they were wear-resistant they did wear out. There was world-wide, at the time, acceptance of continuous-casting so there was continuous need for these ceramic linings and the one [continuous process].

So I got two projects in that company. One in terms of the creating the shape of the ceramic linings and another one which was simply a logistical project on how to manoeuvre the finished components.

It was an ongoing business. The ceramics that they used were not large so they were of high value but the company could export them world-wide by air anywhere in the world operating out of the subsidiary airport of Glasgow, Prestwick. They had - the company, had - a very consistent work force, because this was one of very few industries in that part of Scotland and the locals knew it as a local company [and] knew it as a source of continuity of employment. You know, their labour turnover was virtually nil and the skill [level] consequently was quite high.

At one stage I asked them 'Where do you get your raw ingredients?' and they said 'Oh, we get this from an interesting place. It's in Western Australia. It's called Capel. Capel Mineral Sands.'

Ayre Yes indeed. The whole process as described by you fascinates me because it would be operating 24 hours a day 7 days a week wouldn't it?

Wager Oh well, this company was not direct-casting.

Ayre No? I was thinking of direct- casting.

Wager Oh yes.

The continuous-casting had so many advantages. It could be continuous as long as you had the supply of steel but the biggest attraction was that you didn't have to reheat the billets.

Ayre Yes, so you were saving energy weren't you?

Wager Saving energy, reducing pollution, etc.

Ayre The point I'm, sort of, coming to understand I think is that the reliability of that ceramic lining was crucial wasn't it?

Wager Mmm. And yet it was their source of income because they wore out.

Ayre Indeed.

Wager But they were exporting to Brazil [and] to Australia.

Ayre So how did they replace the ceramic lining when it wore out?

Wager Oh well, although it was continuous-casting for a pour it wasn't necessarily continuous.

Ayre I see.

Wager It's the same as relining a blast furnace. You have four blast furnaces and three operating.

Ayre So they would have that down-time?

Wager Intermittent down-time.

Ayre Yes. Fascinating though isn't it?

Wager Well I found it so.

Ayre Oh yes.

So were there any other projects you got involved in up in Scotland?

Wager Oh yes. One [that I] had in the back of my mind because [of] the Scottish lace making industry, I was told up there - I hope it was right - preceded [the lace making industry in] Nottingham. I mean you say 'Nottingham' these days and that is where lace is linked [with] but, apparently, very early were the enclosures [of the open lands] and the [resulting] Scottish migration to Canada and Australia and whatever they had developed [went with them]. The making of lace it was a craft.

Ayre I suppose it could have started as a cottage industry couldn't it?

Wager Yes very much so. There was one company that was using computers. Or early versions of computers, the old punch-card [system].

Ayre Oh yes I remember.

Wager You remember those?

Ayre Yes I do.

Wager Well these were punch-card systems for making of lace. Quite complex.

Wager There [were] two projects there too. So that was quite a challenge.

Ayre Oh indeed. You certainly had some exposure to the north of England and Scotland then haven't you?

Wager Mmm.

Ayre So you learnt a few languages in your time?

Wager Oh yes and met some lovely people in the process.

6 Ayre Right John, so you spent a fair bit of time travelling around the world and certainly the north of England and Scotland. I think you mentioned a while ago you had some involvement with the Isle of Man?

Wager Ah yes. My maternal grandfather was from the Isle of Man and the family history from some aged aunts was very interesting about early life in the Isle of Man. Because in that period of '92/93 when I was a

resident up in Lancashire, [and] perhaps being flushed with my success in the Darvel Valley, I suggested to Cambridge that I might be able to find some suitable projects in the Isle of Man; thinking, you know, 'if they say no well you haven't lost anything and if they say yes I could revisit some old historic family sites'.

They said yes and then I thought 'oh'.

Ayre That did it didn't it?

Wager Yes. [I then asked myself] 'what can I find on the Isle of Man?'

Well I did some [research]. Fortunately there's a lot of industrial recording [and] sources of information and government publications and the like. So I did some research and I found some amazing bits. The airport is Ronaldsway on the Isle of Man and to my surprise I discovered that there was a company on the outskirts of the airport who were making parts of [aircraft] ejection seats.

Ayre You keep coming back to the aircraft industry don't you?

Wager Well it keeps coming back to me. I just look and it arrives. But that was fascinating.

So we had two projects there. Up in the north, up in Ramsey, tourists who drive through Ramsey would see [and] they'd think it's a bit old fashioned. There are some old World War II huts here and there [and] I discovered that in a collection of those World War II huts there was an entrepreneur who specialised in making elements for hot water jugs which he was marketing quite successfully on the continent of Europe. Apparently there were only two or three manufacturers of the elements although they ended up in hot water jugs [and] hot water kettles with various names. You know 'Hotpoint' and whatever? He was the supplier. He had an amazing organisation there and that provided another two projects.

Ayre Yes, there's often quietly behind the scenes some quite interesting stuff going on isn't there?

Wager Mmm.

7 Ayre My name is Doug Ayre the date is the 26th of August 2013 and I am continuing with the interview of Dr John Wager.

John, I'd like to just pick up on the time that you spent at Hunan University in China. What were you doing there?

Wager Well that was quite interesting. Around 1988 I had as a graduate student a first-degree engineer from Hunan University. He was quite a diligent and competent student and he secured an invitation for me and a fellow colleague of mine, Professor Stone, to go to Hunan University to give a series of lectures over a week or eight days. It was arranged that this visit followed a CIRP conference that both Brian Stone and I were attending in Tokyo so from transport point of view it was quite sequential.

We flew into Beijing and were welcomed there by representatives of

Hunan University and then had a pleasant train ride down. The lectures were well received [and] it was obvious from the audience that we had not only senior students of Hunan University in the audience but also members from industry in the local area. It was interesting spending prolonged periods working with an interpreter. Quite strange really. I'm sure we got the message across, that was not a problem, but sometimes we'd be [distracted]. I would have uttered a few paragraphs and I'd realise 'oh I should pause and let the interpreter pick up' which he did. Then on other occasions I would say a short sharp sentence and he'd respond with paragraphs. It was quite an educative transfer [and] both Brian and I felt, I certainly felt, that we were learning as well as teaching.

Ayre So you were there a week were you?

Wager Mmm, yes.

Ayre In retrospect was it interesting?

Wager Oh yes it was. Technically it was interesting to get their responses. From a sociological view it was interesting. We lived on campus. It was a sort of a campus town. The whole university were resident there on campus, and just things we saw in the travel - we went down by train from Beijing to Changsha and then continued south down to Guangzhou and then home via Hong Kong.

The particular subjects I was looking at were 'quality in manufacturing' and 'control of quality'.

Ayre Now I'd like to continue on then from your retirement in WA, or UWA I should say, which I think was in 1998. You did some work in Indonesia. What did you do there?

Wager Well, in late 1997 I retired and I thought I could live the life of a retired gentleman and go sailing but I was almost head-hunted into a fascinating project in Indonesia. It was a project for the Asian Development Bank and the Indonesian Government which differed from, I think, in all previous tertiary [consulting] involvements. Previous consultancies had been with a particular institution - some trade schools, some universities, some departments, within the university - but this particular one was a broad across the whole spectrum.

The ultimate purpose was two-fold. First, number one, was to develop new curricula for civil, mechanical, electrical, chemical engineering. So there were a total of 22 consultants involved. Not all at once. Some consultants from Australia were there for the whole time of the project [and] others were called in as necessary. The idea was on the United Nations pattern; for every consultant visiting there was a resident engineer who was an effective counterpart. I found in mechanical engineering the folk I was dealing with in the various institutions had - most had - PhDs. Some from Australia, a lot from America and not surprisingly some from the Netherlands.

The second objective was to do something that I had been involved in

with the Institution of Engineers in Australia in the latter years of my time at the UWA. That was that the Institution in Australia had been developing systems for accreditation for professional engineering. Australia had become one of the signatories to what's now known as the 'Washington Accord'. Nations with quite a good tertiary institution development in engineering [that had developed] their own systems for accreditation which were internally audited. So the idea was to help engineering in Indonesia along these lines by taking some early steps - that is encouraging the staff in the universities to develop the attitude and the abilities to continually improve their curricula.

I got the impression over the project that the staff in the Indonesian institutions were rather expecting a package from outside and applying it rather than seeking to develop it and that was the trickier part of our twofold objective.

It was a fascinating year - well actually for me it was about 15 months - because I was at the time still Chairman of the Mechanical College for the Institution in Australia. I had secured approval from the Indonesian Government that, where necessary, I could fly down to Australia to chair meetings of the IEAust Mechanical College.

Being Indonesia-wide it meant that we had to consider some 52 tertiary institutions. It would be physically impossible to visit them all so we categorised them into group 'A's, group 'B's, and group 'C's. The group 'A's were really of international calibre and it went off into a longish tail into the group 'C's. I forget the exact number that we visited but I'm trying to identify typical universities in each category.

It was a very interesting year not only for the project but also for its nature because geographically we had to cover the whole archipelago and there are some, what is it, 17,000 islands in Indonesia?

Ayre I have to confess that I don't know much about Indonesia but it is pretty extensive isn't it?

Wager Yes it is.

So we did quite a bit of travelling which I personally found interesting. It was also a bit salutary for me too because I thought 'oh I understand the culture a little' because my father was actually born in Singapore and as young children he used to speak to us in Bahasa, the Malaysian language, [which] is very similar to Indonesian [using] phrases like 'time for bed' and so on. But the culture just in Java for example was fascinating. That was a background where we were learning as well as teaching.

Also significant things were happening. In 1998 that, of course, was the year of the great uprising. At UWA I'd been used to students having complaints about the exam questions and there would be a knock on the door and I'd open it and there'd be two or three students and they didn't like this or that question and we'd sit down and talk about it. But when there was an uprising at some of the universities we were visiting we saw something like 5,000 to 10,000 students in

the large quadrangle protesting about the nature of the government nepotism, cronyism, and financial mismanagement. That was quite an experience.

We did complete the project and I'm sure the project had some effect but the 12 months had quite an effect on us. Particularly because in May 1998 we weren't just observing the unrest in Jakarta, we were involved in it. We found it was prudent to close our office and withdraw to apartment residences and bring our three drivers and the vehicles with us and set up our computers and communication in our accommodation.

At that time there were only four Australians resident at that stage of the project and in May, on the period of the 15th and 16th, there had been some student protests in the streets. Apparently there was a tacit agreement between the military and the students that the students could have a protest gathering inside their campus but not on the streets. Well on May the 14th I think it was in the Trisakti University there was a student gathering and such was the atmosphere that had developed at that time it took just one military person to fire and he did. They [then] fired into the students, into the university, killed three students and what followed was not an immediate uprising but a sort of 'deathly' - if that's the right adjective - silence for 24 hours and that's when we consolidated our transport and communications to our apartments. Then on the following day, I think it was the 16th of May, the rioting took [off]. Just erupted.

There were about five reasons for dissent there. One was the falling in value of the rupiah. We were getting, oh I don't know, about 12,000 rupiah for one dollar. The price of rice, the staple diet, [had increased]. There was no safety net. There was no social structure. Fortunately it wasn't anti-foreigners but there was a strong anti-Chinese feeling. Chinese had been resident and active in Indonesia for decades and they had done two things that the Indonesians were a bit slow about doing. That is they interacted and networked and then they worked and so that the fires we saw burning included a lot of Chinese businesses.

But the most potent reason was this anti-government feeling, the nepotism - the misuse of funding. It was a most interesting period. Our drivers, the three drivers and three four-wheel drive [vehicles] that we had for working in Java, had red-backed number plates which indicated not government transport but a para-government activity. Our drivers cannily realised that they and the vehicles might be subject [to abuse] so in that quiet period they had magically transferred our number plates to white background. On that day of the rioting from my own apartment which was 22 stories high I could see over a dozen properties on fire.

I mentioned there were four of us. One was the team leader, a man from Perth, and his wife. For me this was a, sort of, a one-off consultancy lasting for that period but for them as a couple they had been previously in Indonesia on previous specific campus projects

and she had the wisdom to get us together for the 'last supper' because none of us knew what might happen the next day.

In fact on that afternoon what I, and he of the couple, did was to walk down the 22 flights of stairs so that we could make sure that the exit door from the stairwell was unlocked from the inside so that we could escape. The second thing we did was to plan where we would go immediately those doors were opened so that we were not left standing in the doorway being very vulnerable.

Later that afternoon we could see a quite a large black-smoke fire at the junction of the road in front of our apartment block and another [at an] intersecting road at a T intersection. At that junction, this building housed the Goodyear Tyre importing company for the whole of the Jakarta. Once you've seen what happens with a whole [tyre] store, it was dramatic.

There were two groups of insurgents at the cross-members of the T. They had met and presumably set fire to this but we were wondering were they going to turn [and] come down the leg of the T which was our address. Fortunately they didn't and we survived. Obviously we survived but it was a very interesting period deciding what we would do if we had an hour to get things together. Obviously we might take a laptop and passports and the like but [we would have only] what we would have about us and [to decide] how we'd conceal it if the door suddenly opened and we had to run.

Yes interesting diversions to a project that itself was interesting.

Ayre So you survived your spell in Indonesia then, clearly.

You mentioned in passing a couple of the roles that you played with the Institution of Engineers. I'd like to just get you to review the roles that you've had with the Institution over what I would suggest is quite a few years.

Would you like to do that for me please?

Wager Yes Doug.

I joined in Perth as a student member in 1953 so that means I've been over half a century a member of the Institution. I joined the Mechanical Branch in WA in 1967 and served on that branch until 1982. I became its Chairman in 1989.

I served on the WA Division committee in 1981, 1987/88/89, and was Chairman of the WA Division in 1990.

I served on the National Committee on Manufacturing Engineering 1975/81 and 1983/85 and I was a member of the Mechanical College Board from 1995 to 1999. I was Chairman 1998/99.

I was a member of National Council 1999/2002. I was a member of National Congress for the same period. I was National Vice President for Education and Assessment 1999/2001 and I served as National Deputy President in 2002.

- Ayre That's what I call an extensive involvement.
- Wager Well yes. Yes it was, but my lifelong interest was engineering and therefore I was interested in what the Institution was able to do and was doing.
- Ayre Yes. Do you have a current involvement with the Institution?
- Wager No. Well I'm an Honourary Fellow of the Institution.
- Ayre Yes.
- Wager No, my greatest activity is talking to you right now.
- Ayre What can I say? Alright well thank you for that John that's very interesting.
- Now we're really, sort of, in the closing stages of this oral history so I think you've got some thoughts that you would like to explain to me? What I suggest we do is we'll stop here and we'll start a new track.
- 8 Ayre Now John I'd like to get your comments then on what you've been able to contribute to the profession and the development of the areas that you've been interested in.
- Wager Yes, thank you Doug.
- I'm so far trying to describe the wider education and the information I've definitely gained during my own life and travels but before concluding this interview I feel I should make some comment on the value I believe I've been able to contribute in return to UWA and Australia for the study leave grants and the Fulbright travel grant which enabled my contact and work with CIRP and ACDMM.
- In my teaching at UWA I was presenting conventional methods of manufacture as a general mechanical background, and my interest in gears assisted understanding one particular company that was manufacturing precise large diameter gears for heavy duty operations for continuous operating ball rolling mills and intermittent tiplers for emptying iron ore railway wagons. It required precise gears but of some strength.
- But in addition when it became possible from time to time I introduced new methods of manufacture. I think we've already mentioned electro-discharge machining, the electro-discharge erosion of a mould typically for plastic die-sinking, but also for shaping in very hard materials. We developed an experimental rig for EDM as it's known in the mechanical department. There's also a parallel process called electro-chemical machining where the erosion is by chemical erosion and that was of use for some of my post graduates as a manufacturing aid for some of their items
- Ayre I'll just pause you there. So chemical erosion works [in that] you mask what you want to protect and then allow the chemistry to do the work on the exposed bit?
- Wager That's right. Whereas the electro-discharge machining was with an electrical conductive electrode and the work-piece both being

immersed in a dielectric which allowed a discharge current. So effectively a series of sparks which don't affect the shape of the mould. As I mentioned earlier the mould - the electrode making the shape - can be in carbon actually but soft and easily finished and the erosion is caused to effect by sparks impacting on the metal on the work piece.

Another new method over my years at UWA was the laser. A high powered and carefully focussed laser can cut steel and one WA company was using laser cutting of steel and aluminium for many engineering requirements. Also much more widely for general community use laser cutting of lettering for stick-on signs is one end of that ability spectrum.

Another area that I helped to develop was computer-aided-design and computer-aided-manufacturing known as CAD and CAM. I established a laboratory with 12 computer places for mechanical engineering students to develop their skills in computer-aided-design. We replaced the old conventional drawing board and T-square drawing offices with computers. Soon after that laboratory was equipped with a computer-driven lathe and a computer-driven milling machine so the students could design and manufacture items to their own specifications in metal.

These skills were later to become very widely used in the industrial trade areas of drafting and machining and so teaching them became increasingly presented by the TAFE organisation in WA.

I had responsibility in my years with UWA for the Mechanical Department Metrology Laboratory which was equipped for fine measurements using slip blocks, and an optical projector and we had access to an electron microscope through the physics department. In the mechanical engineering third year I taught a course on Inferential Statistics [which are] useful as a means of providing quantitative evidence for decision making.

I covered work-study techniques for organising and measuring repetitive manual work. I taught linear programming and operation research applicable both to mechanical manufacturing and also to the planning and control of large mining and civil engineering projects.

I, as I mentioned earlier, taught industrial safety by a project somewhat similar to the ACDMM projects that I've previously described. Each final year I contacted a manufacturing company willing to have a small group of students visit while working on the project. The project ran over a month with a focus on industrial safety. It required the students to prepare a written report on the nature of the product and particularly the organisation for producing it with a focus on safety including their suggestions for any improvements. It provided for an extensive visit to the plant or factory and included lectures both from me and then a senior staff member of the company and also a speaker from the Industrial Foundation for Accident Prevention, IFAP. Students both

mechanical and civil were likely to meet IFAP later in their professional careers for which this proved to be a useful introduction.

I recall a project one year on fire safety. Perth airport agreed for the group to attend a demonstration of a possible aircraft fire. A steel-framed replica of an aircraft fuselage exists in a remote location of the airport property and a sudden fire can be created there by high pressure inflammable gas. The experience of the sudden wall of flame and the physical pressure of the wall of hot air preceding it made a lasting impression on everyone present. It also illustrated the futility of a hand held fire extinguisher in such dire circumstances, much more effectively than any words in a lecture.

Ayre Yes I think to say that you'd be speechless is true isn't it?

Wager Yes. Yes it got the message across.

I also taught effective professional communication both in written reports and verbally and I even ran a short series of lectures on body language which was also well received. In addition to my own interest in developing and presenting these topics I'd been approached and contacted by a number of past-students during my study-leave travels and since retirement and they have commented that they found these senior-year topics of value in their own professional work. This was good to know after what I feel has been my own fortunate life with many opportunities and a wide range of experiences.

Ayre Thank you.

I suspect you've created many of the opportunities for yourself. And so you should of course.

Wager Yes, well, yes.

Ayre It's interesting isn't it because opportunity doesn't just fall into your lap does it?

Wager No, but if you keep your eyes open, and your ears open, doors open.

Ayre That's right indeed.

I made a couple of notes here on my scratch-pad just to follow up areas that particularly interest me. One of them was linear programming. I found that fascinating.

How was it applied in the mechanical manufacturing area?

Wager Oh really in industry control.

Yes, movement around [and] within a plant.

I was recounting my time in America noting the wide dispersion of components for a manufacturing company and so [it involved] just the logistics of storage and transport [for] 'just-in-time' manufacture.

Ayre Yes. There are significant constraints aren't there on the supply of materials if you don't get that 'just-in-time' concept right aren't there?

Wager Yes. That's quite a problem.

Ayre Yes. Alright. Now the other subject which has also fascinated me for a long time is that of body language.

Wager Yes.

Ayre I suspect you enjoyed that did you?

Wager Well I did. I mean right [from] the start. Obviously when one's a very junior lecturer as I was in my first appointment [then] almost by subtraction you seem to get first-year lectures on your program. I found that very interesting just watching the students while I was presenting the lecture and a number of students thinking with their eyes closed.

Ayre You're not suggesting they were asleep are you?

Wager Oh never!

Ayre Body language is one of those inputs isn't it that you intuitively accept without thinking about it? But it is quite powerful isn't it?

Wager Oh yes. Well you as an interviewer must have noticed this?

Ayre Yes indeed. Yes you can certainly tell whether you're engaging with the person you're interviewing.

Alright, well engaging with you John has been fascinating and very, very enjoyable.

Wager Well thank you.

Ayre So I'd like to thank you for sharing this with me and we'll conclude there I think.

Wager Thank you Doug. Thanks for your patience.

Ayre My pleasure.